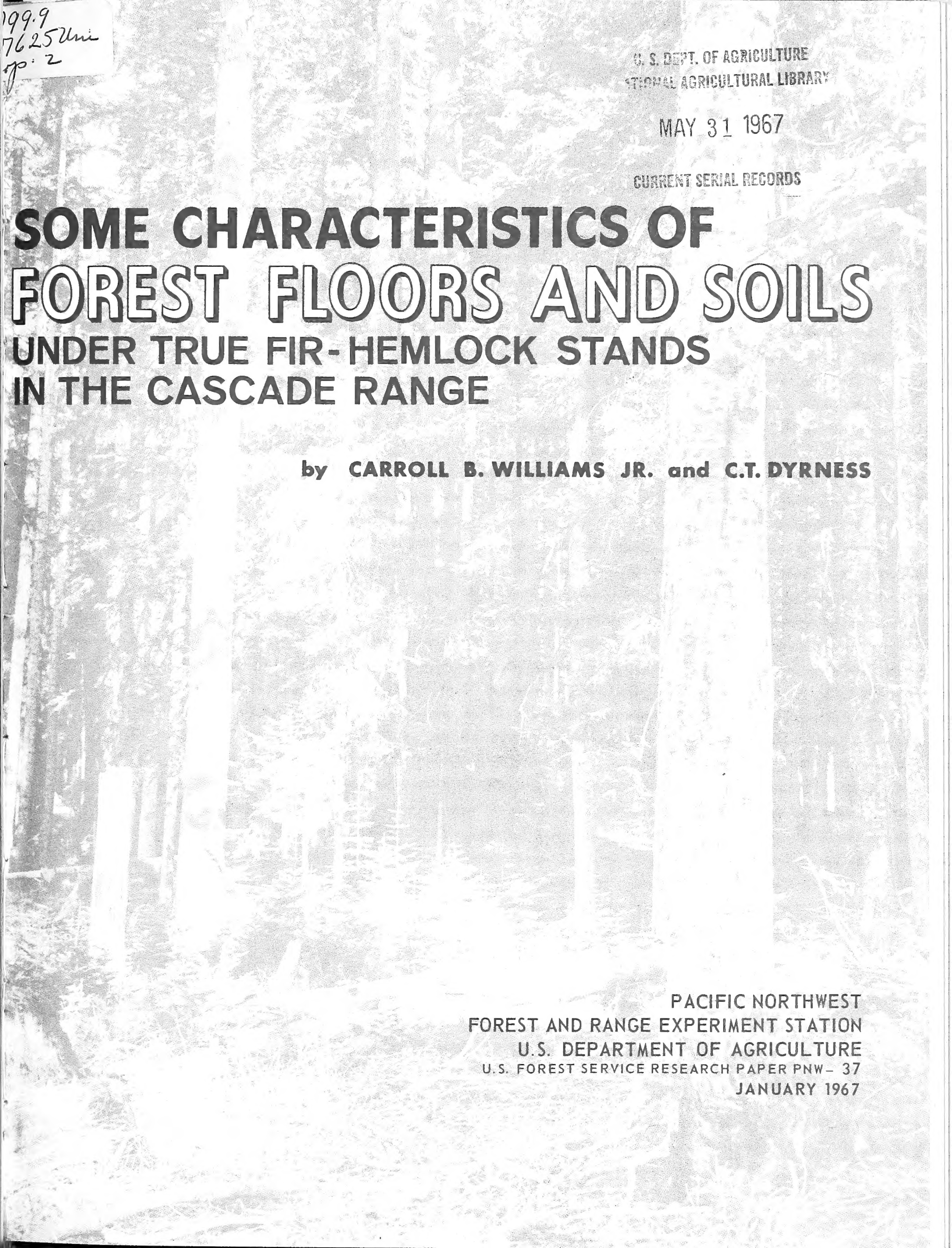

SOME CHARACTERISTICS OF FOREST FLOORS AND SOILS UNDER TRUE FIR-HEMLOCK STANDS IN THE CASCADE RANGE

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INTRODUCTION

The forest floor[1/] is an important component of the forest ecosystem. This layer of organic material influences tree regeneration, protects the surface soil from erosion, and may substantially affect hydrologic properties of the site. Probably one of the most important aspects of the forest floor is its role in the nutrient cycle. Several essential nutrients, such as nitrogen, phosphorus, and sulfur, are supplied primarily by plant residues, and amounts made available depend on decomposition rates. Thus, a large buildup of forest litter on the soil surface may delay nutrient recycling and reduce soil fertility.

Little information is available about forest floor characteristics in the Pacific Northwest. Gessel and Balci (1965) have sampled the forest floor in five areas of old-growth coniferous forests in the Cascade Range and Olympic Mountains of Washington. Youngberg (1966) has investigated forest floor characteristics of eight different Douglas-fir communities in the Coast Ranges of Oregon.

The subject of this paper is an exploratory study of forest floor and soil conditions in true fir—hemlock stands, conducted during 1964. Objectives of the study were to:

1. Describe general characteristics of the forest floor--humus type, depth, weight, available nutrient content, and reaction.

2. Determine general characteristics of the underlying mineral soil--soil depth, texture, available nutrient content, and reaction.

3. Determine the relative amounts of available plant nutrients in the forest floor and in the underlying mineral soil.

[1/] The forest floor is defined as "all dead vegetable or organic matter, including litter and unincorporated humus on the mineral soil surface under forest vegetation" (Soil Science Society of America Committee on Terminology 1965). (Names and dates in parentheses refer to Literature Cited, p. 19.)

STUDY AREAS

Forty-six undisturbed, old-growth true fir—hemlock stands were sampled along the Cascade Range from Diamond Lake in southern Oregon to Mount Baker in northern Washington (fig. 1). Elevation of sampled stands ranged from 2,000 to 6,200 feet. Pacific silver fir *(Abies amabilis)*, [2] noble fir *(A. procera)*, Shasta red fir *(A. magnifica* var. *shastensis)* or mountain hemlock *(Tsuga mertensiana)* were the dominant species. None of the stands were pure, and several contained a major component of western hemlock *(T. heterophylla)* (table 1). The 46 plots probably provide a cross section of sites occupied by true fir—hemlock forests.

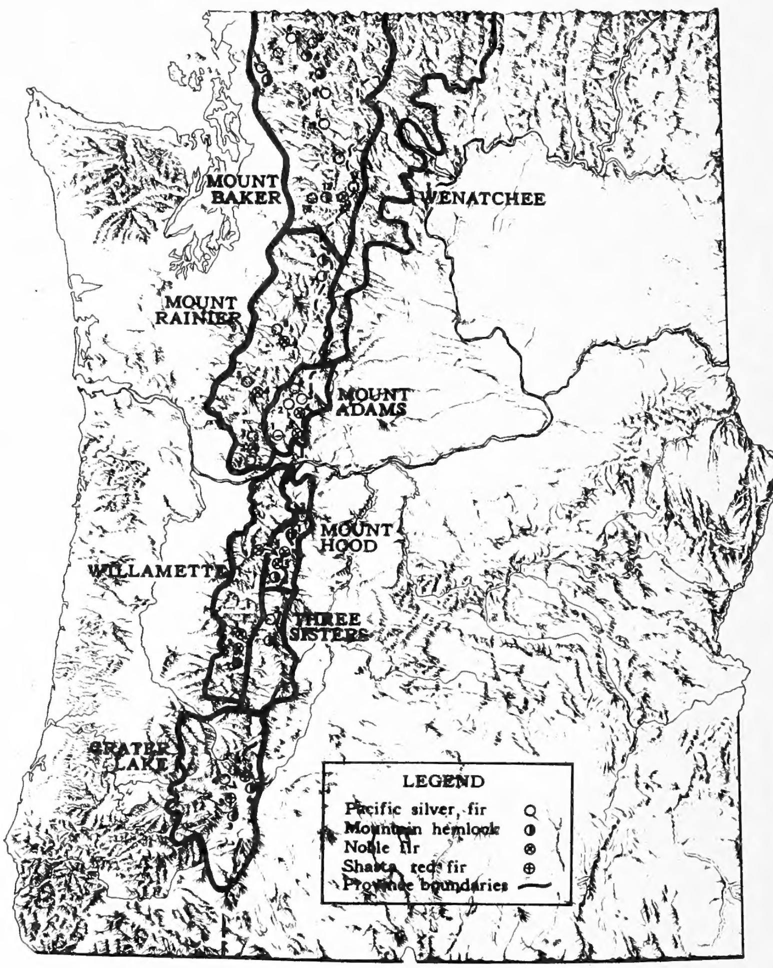


Figure 1.--Approximate locations of the 46 upper-slope forest stands described and sampled in this exploratory study of forest floor and soil conditions.

[2] Common and scientific names of trees are in accordance with Little (1953).

Table 1.--Characteristics of 46 true fir--hemlock plots in 1964 study of forest floors and soils in Oregon and Washington

Ecological province	Plot No.	Elevation	Aspect	Forest type	Additional tree species present[1]	Understory vegetation: Important species (listed in order of dominance)[1]	Understory vegetation: Approximate total cover
		Feet					Percent
Crater Lake, Oregon	1	5,050	SW.	Shasta red fir	Mountain hemlock *(Tsuga mertensiana)* and western white pine *(Pinus monticola)*	*Vaccinium scoparium, Chimaphila umbellata*	15
	2	5,150	NE.	Shasta red fir	Mountain hemlock, scattered lodgepole pine *(P. contorta)* and western white pine	*V. scoparium, Arctostaphylos nevadensis*	10
	3	6,200	Level	Mountain hemlock	Subalpine fir *(Abies lasiocarpa)*	*V. scoparium*	10
	4	3,800	S.	Pacific silver fir	Douglas-fir *(Pseudotsuga menziesii*, and western hemlock *(T. heterophylla)*	*Acer circinatum, Berberis nervosa, Linnaea borealis, C. umbellata,* many other herbs	85
	5	5,400	Level	Shasta red fir	Pacific silver fir *(A. amabilis)* and western white pine, scattered mountain hemlock and Douglas-fir	*V. membranaceum, C. umbellata, Rubus lasiococcus*	85
	6	5,800	Level	Mountain hemlock	Lodgepole pine and Pacific silver fir, scattered western white pine	*V. scoparium*	60
Three Sisters, Oregon	1	4,750	Level	Mountain hemlock	Scattered Pacific silver fir	*Xerophyllum tenax, V. membranaceum, V. scoparium*	95
	2	3,450	E.	Noble fir	Douglas-fir and western hemlock	*X. tenax, Cornus canadensis, V. membranaceum, R. lasiococcus,* many other herbs and shrubs	100
Willamette, Oregon	1	4,250	S.	Noble fir	Pacific silver fir, scattered mountain hemlock and western white pine	*R. lasiococcus, V. membranaceum,* several other herbs	25
	2	4,300	S.	Noble fir	Douglas-fir, scattered Pacific silver fir and western white pine	*A. circinatum, Smilacina sessilifolia, Clintonia uniflora, Pteridium aquilinum,* many other herbs and shrubs	100
	3	5,200	S.	Mountain hemlock	Noble fir *(A. procera)*, scattered western white pine	*X. tenax, V. membranaceum,* several herbs	100
Mount Hood, Oregon	1	4,500	S.	Mountain hemlock-Pacific silver fir	Scattered western white pine and Douglas-fir	*V. membranaceum, X. tenax, R. lasiococcus,* several other herbs	100
	2	4,500	E.	Pacific silver fir-mountain hemlock	None	*V. membranaceum, X. tenax, R. lasiococcus, V. scoparium*	95
	3	4,500	NW.	Noble fir	Douglas-fir and western hemlock	*A. circinatum, Arnica* sp., *V. membranaceum,* many other herbs and shrubs	100
	4	4,250	NE.	Mountain hemlock-Pacific silver fir	Scattered western hemlock, noble fir, and western white pine	*X. tenax, V. membranaceum, C. umbellata,* several other herbs and shrubs	100
	5	4,500	E.	Noble fir	Douglas-fir and mountain hemlock, scattered western hemlock and Pacific silver fir	*X. tenax, V. membranaceum, C. umbellata,* several other herbs	100
	6	4,600	N.	Noble fir	Douglas-fir, western hemlock and Pacific silver fir, scattered western white pine	*X. tenax, C. canadensis, V. membranaceum,* several other herbs	10

See footnote at end of table.

Table 1.--Characteristics of 46 true fir–hemlock plots in 1964 study of forest floors and soils in Oregon and Washington --*Continued*

Ecological province	Plot No.	Elevation	Aspect	Forest type	Additional tree species present[1/]	Understory vegetation: Important species (listed in order of dominance)[1/]	Understory vegetation: Approximate total cover
		Feet					Percent
Mount Adams, Washington	1	3,800	Level	Pacific silver fir	Scattered mountain hemlock	*R. pedatus, X. tenax, V. membranaceum, V. ovalifolium,* many other herbs and shrubs	100
	2	5,000	S.	Pacific silver fir	Scattered Douglas-fir, noble fir, and subalpine fir	*X. tenax, R. lasiococcus, V. membranaceum,* several other herbs	90
	3	3,900	Level	Pacific silver fir-mountain hemlock	Scattered western white pine, Douglas-fir, and western hemlock	*V. membranaceum, C. uniflora, V. ovalifolium,* many other shrubs and herbs	100
	4	4,800	S.	Pacific silver fir-mountain hemlock	Scattered Douglas-fir, western hemlock, western white pine, western redcedar *(Thuja plicata)*	*V. membranaceum, R. lasiococcus,* several other herbs	50
	5	4,000	NW.	Noble fir	Douglas-fir, scattered Pacific silver fir and western hemlock	*V. membranaceum, C. canadensis,* many other herbs and shrubs	100
	6	4,000	W.	Noble fir	Douglas-fir and Pacific silver fir, scattered western hemlock and western white pine	*A. circinatum, Tiarella unifoliata, Achlys triphylla,* several other herbs and shrubs	100
Mount Rainier, Washington	1	3,500	E.	Pacific silver fir	Noble fir	*X. tenax, V. alaskaense, V. membranaceum,* several other herbs	90
	2	3,500	S.	Pacific silver fir	Noble fir, scattered western white pine and Douglas-fir	*A. triphylla, Thalictrum* sp., *A. circinatum, Smilacina* sp., several other herbs and shrubs	100
	3	2,900	E.	Pacific silver fir	Scattered Douglas-fir, western redcedar, western hemlock	*V. alaskaense, C. canadensis, R. pedatus, X. tenax,* several other herbs	100
	4	3,600	W.	Noble fir	Douglas-fir and western hemlock, scattered Pacific silver fir	*V. alaskaense, T. unifoliata, P. aquilinum,* several other herbs and shrubs	100
	5	2,700	N.	Pacific silver fir-western hemlock	Scattered western redcedar	*Oxalis oregana, T. unifoliata, P. aquilinum, R. pedatus,* many other shrubs and herbs	100
	6	3,600	E.	Mountain hemlock-Pacific silver fir	Scattered western hemlock	*Arnica* sp., *P. aquilinum, V. ovalifolium, A. triphylla,* many other shrubs and herbs	100
	7	3,600	Level	Pacific silver fir-mountain hemlock	Scattered Douglas-fir, western hemlock, western white pine	*V. ovalifolium, V. membranaceum, C. uniflora,* several other herbs and shrubs	90
	8	4,500	N.	Pacific silver fir	Scattered mountain hemlock	*V. membranaceum, R. lasiococcus, X. tenax, V. ovalifolium,* several other herbs	100
	9	4,600	SW.	Noble fir	Douglas-fir, Pacific silver fir, western hemlock	*A. circinatum, C. uniflora, A. triphylla,* many other shrubs and herbs	100

See footnote at end of table.

Table 1.--Characteristics of 46 true fir–hemlock plots in 1964 study of forest floors and soils in Oregon and Washington --*Continued*

Ecological province	Plot No.	Elevation	Aspect	Forest type	Additional tree species present[1/]	Understory vegetation: Important species (listed in order of dominance)[1/]	Understory vegetation: Approximate total cover
		Feet					Percent
Mount Baker, Washington	1	4,500	S.	Mountain hemlock-Pacific silver fir	Alaska-cedar *(Chamaecyparis nootkatensis)* and western hemlock	*Arnica* sp., *Menziesia ferruginea*, *V. ovalifolium*, *R. pedatus*, many other shrubs and herbs	100
	2	4,800	E.	Pacific silver fir	Scattered mountain hemlock	*V. membranaceum*, *R. pedatus*, *T. unifoliata*, *C. uniflora*, several other shrubs and herbs	100
	3	3,750	SW.	Pacific silver fir-western hemlock	None	*V. ovalifolium*, *R. pedatus*, *M. ferruginea*	100
	4	4,700	S.	Pacific silver fir-mountain hemlock	None	*M. ferruginea*, *V. ovalifolium*, *V. membranaceum*, *R. pedatus*, *Sorbus sitchensis*	100
	5	4,500	W.	Pacific silver fir-western hemlock	Mountain hemlock	*R. pedatus*, *Arnica* sp., *R. spectabilis*, many other shrubs and herbs	100
	6	2,000	N.	Pacific silver fir-western hemlock	None	*V. alaskaense*, *R. pedatus*, *C. canadensis*, several other herbs	100
	7	4,300	W.	Mountain hemlock-Pacific silver fir	Scattered Alaska-cedar	*V. membranaceum*, *V. ovalifolium*, *P. aquilinum*, many other shrubs and herbs	95
	8	4,500	W.	Pacific silver fir-western hemlock	None	*R. pedatus*, *V. alaskaense*, *C. uniflora*, several other herbs	90
	9	3,200	E.	Pacific silver fir-western hemlock	None	*V. alaskaense*, *R. pedatus*, *L. borealis*, *C. uniflora*, several other herbs	100
	10	3,500	NW.	Pacific silver fir	Scattered western hemlock and mountain hemlock	*V. alaskaense*, *V. ovalifolium*, *T. unifoliata*, *R. pedatus*, *Streptopus curvipes*, *C. uniflora*, several other herbs	90
	11	2,800	W.	Pacific silver fir-western hemlock	Scattered noble fir and western redcedar	*V. ovalifolium*, *S. curvipes*, *T. unifoliata*, *C. uniflora*, many other shrubs and herbs	100
	12	2,800	W.	Noble fir	Western hemlock and Pacific silver fir	*P. aquilinum*, *Smilacina* sp., *T. unifoliata*, *Oplopanax horridum*, many other shrubs and herbs	100
	13	4,500	W.	Mountain hemlock-Pacific silver fir	Scattered western redcedar and western hemlock	*V. ovalifolium*, *M. ferruginea*, *R. pedatus*, *R. lasiococcus*, many other shrubs and herbs	100
	14	4,500	E.	Pacific silver fir	Scattered western hemlock	*V. ovalifolium*, *R. pedatus*, *C. uniflora*, *Streptopus amplexifolius*, many other shrubs and herbs	100

1/ Common and scientific names for trees are in accordance with Little (1953); for shrubs and herbs, Peck (1961) or Hitchcock et al. (1955-1964).

METHODS

Representative and homogeneous portions of each stand, free from road influences or major disturbances, were subjectively selected and two 1/5-acre plots established. On each plot all trees, shrubs, and herbs were listed and relative abundance estimated.

Total depth of the forest floor was measured to the nearest one-tenth inch at eight randomly located points within the first plot and at seven points in the second. Pronounced depressions and humps were avoided. The forest floor was carefully examined during measurement and classified according to the key devised by Hoover and Lunt (1952). A circular sample of forest floor material with 28.5 square inches of surface area was collected at two random points within each plot for later measurements of weight and available nutrient content.

The mineral soil was sampled at four or more random points within each stand with a King tube sampler. At each point, the King tube was driven into the soil until stopped by bedrock or a stony layer. Depth of penetration was recorded to the nearest one-tenth foot and was used as an index of effective soil depth. All soil samples from a given stand were composited into a single sample. Soil texture, approximate bulk density, and content of available plant nutrients were determined for the composite samples.

Soil samples were air dried, forest floor samples were ovendried at 70° C., and all samples were then weighed and weight recorded to the nearest one-tenth gram. Forest floor samples were ground to pass a 40-mesh sieve in a Wiley mill. The following chemical determinations were carried out on both forest floor and soil samples: reaction (1:1 soil-water paste with a glass electrode pH meter); amounts of total nitrogen (Kjeldahl method); available phosphorus (sodium bicarbonate method); and exchangeable calcium, exchangeable potassium, and exchangeable magnesium (flame photometer method). Oregon State University Soil Testing Laboratory made the analyses, using the procedures described by Alban and Kellogg (1959).

RESULTS

Timber Stand Characteristics

Stands were sampled in seven of the eight ecological provinces suggested for the Cascade Range in Oregon and Washington (table 1 and fig. 1) (Franklin 1965). The Wenatchee Province was not sampled.

The timber stand at each plot was classified into one of seven forest types on the basis of relative abundance of the various tree species. Each type bears the name of the most common tree species; and, in the case of hyphenated designations, the first-named species is most abundant. Forest types sampled include Shasta red fir, noble fir, Pacific silver fir, Pacific silver fir–western hemlock, Pacific silver fir–mountain hemlock, mountain hemlock-Pacific silver

fir, and mountain hemlock. Most stands were mixed with at least small numbers of other tree species (table 1). Western white pine, Douglas-fir, and western redcedar were common subordinate species.

Understory vegetation was generally abundant and apparently somewhat correlated with ecological province (table 1). Small-leaved huckleberry *(Vaccinium scoparium)*[3/] was the dominant shrub species on most plots in the Crater Lake Province. The understory in the two Three Sisters plots was dominated by bear-grass *(Xerophyllum tenax)* and thin-leaved huckleberry *(Vaccinium membranaceum)*. Plots in the Willamette Province were similar to those in the Three Sisters except for one plot with an understory of vine maple *(Acer circinatum)* and a variety of herbs and shrubs. Understory vegetation on the Mount Hood Province plots was also generally dominated by thin-leaved huckleberry and bear-grass. In the Mount Adams Province, the principal understory species on the plots were thin-leaved huckleberry, oval-leaved huckleberry *(Vaccinium ovalifolium)*, bear-grass and dwarf bramble *(Rubus lasiococcus)*. These same species plus Alaskan huckleberry *(Vaccinium alaskaense)*,[4/] were common on five of nine plots within the Mount Rainier Province. The other four plots were characterized by herbaceous species such as vanilla-leaf *(Achlys triphylla)*, western brake-fern *(Pteridium aquilinum)*, arnica *(Arnica* sp.*)*, and Oregon oxalis *(Oxalis oregana)*. On six plots within the Mount Baker Province, oval-leaved huckleberry or Alaskan huckleberry were the dominant understory species. Other shrubs common on the plots within this province were thin-leaved huckleberry and strawberry dwarf bramble *(Rubus pedatus)*. Common herbaceous species included arnica, western coolwort *(Tiarella unifoliata)*, one-flowered clintonia *(Clintonia uniflora)*, and western brake-fern.

Forest Floor Characteristics--Humus Type, Depth, and Weight Relationship

Four forest humus types were identified on the study plots. The following definitions are those proposed by Hoover and Lunt (1952).

1. Felty mor--H layer (02 horizon) present and practically no mixing of organic matter with mineral soil. H layer feels and looks felty due to presence of fungal hyphae.
2. Fine mull--No H layer present. A1 horizon is an intimate mixture of organic material and mineral soil, has fine granular structure, and organic matter content is generally greater than 30 percent.[5/]

[3/] Common and scientific names for most shrubs and herbs in accordance with Peck (1961).

[4/] Authority for this species is Hitchcock et al. (1955-1964).

[5/] Unfortunately, this definition does not conform to present concepts. Most soil scientists in the Pacific Northwest probably would classify a layer with an organic matter content approaching 50 percent as an H layer, rather than as an A1 horizon.

3. Thin duff mull--H and F layers present with an underlying A1 horizon. Combined F and H layers less than 1 inch thick.

4. Thick duff mull--Combined F and H layers more than 1 inch thick.

The felty mor humus type predominated in the southern provinces (Crater Lake, Three Sisters, and Willamette), whereas the duff mull types were confined almost exclusively to the Mount Baker Province (table 2). Plots within the Mount Hood, Mount Adams, and Mount Rainier Provinces generally had either fine mull or felty mor humus types.

Average values for depth and weight by ecological province show greater accumulations of forest floor material in central and northern Washington compared with Oregon and Mount Adams Provinces (table 2).

Table 2.--General characteristics of the forest floor and underlying mineral soil on 46 true fir—hemlock plots

Ecological province	Plot No.	Forest humus type	Average depth of forest floor	Weight of forest floor	Average soil depth	Soil texture
			Inches	Pounds per acre	Feet	
Crater Lake, Oregon	1	Felty mor	1.2	48,766	2.3	Gravelly loamy sand
	2	Felty mor	1.4	44,279	4.6	Pumice sands and gravels
	3	Felty mor	1.6	75,880	1.2	Sandy loam
	4	Felty mor	1.7	39,184	3.0	Silt loam
	5	Felty mor	1.4	43,735	1.9	Silt loam
	6	Felty mor	1.4	47,071	5.0	Pumice sands and gravels
Province means			1.4	49,819	3.0	
Three Sisters, Oregon	1	Felty mor	1.4	78,199	2.2	Sandy loam
	2	Fine mull	.8	23,054	1.8	Sandy loam
Province means			1.1	50,626	2.0	
Willamette, Oregon	1	Felty mor	1.2	44,038	2.5	Loam
	2	Felty mor	1.8	44,163	4.5	Silt loam
	3	Fine mull	1.0	29,237	1.2	Loam
Province means			1.3	39,146	2.7	
Mount Hood, Oregon	1	Fine mull	.7	31,235	1.4	Fine sandy loam
	2	Fine mull	.5	20,020	3.8	Loam
	3	Fine mull	.9	35,179	1.4	Silt loam
	4	Felty mor	1.1	38,212	1.3	Loam
	5	Felty mor	1.3	32,814	1.1	Loam
	6	Fine mull	.8	26,078	.7	Loam
Province means			.9	30,590	1.6	

Table 2.--General characteristics of the forest floor and underlying mineral soil on 46 true fir—hemlock plots--*Continued*

Ecological province	Plot No.	Forest humus type	Average depth of forest floor	Weight of forest floor	Average soil depth	Soil texture
			Inches	Pounds per acre	Feet	
Mount Adams, Washington	1	Felty mor	3.2	94,321	3.1	Loam
	2	Felty mor	2.0	53,317	3.7	Coarse sandy loam
	3	Felty mor	1.7	46,768	2.6	Loamy sand
	4	Fine mull	1.0	38,756	3.0	Sandy loam
	5	Fine mull	.6	16,987	3.1	Coarse sandy loam
	6	Fine mull	1.1	29,299	2.8	Loam
Province means			1.6	46,575	3.0	
Mount Rainier, Washington	1	Felty mor	2.6	152,375	.7	Silt loam
	2	Felty mor	1.4	45,733	1.4	Gravelly loam
	3	Felty mor	2.1	122,898	2.4	Coarse sandy loam
	4	Thin duff mull	1.5	50,105	4.4	Gravelly loamy sand
	5	Fine mull	.5	34,393	4.3	Sandy loam
	6	Fine mull	.8	31,726	1.5	Loam
	7	Fine mull	.7	34,822	2.4	Sandy clay loam
	8	Fine mull	1.1	44,038	3.0	Loamy sand
	9	Fine mull	.9	25,356	4.2	Coarse sandy loam
Province means			1.3	60,161	2.7	
Mount Baker, Washington	1	Thick duff mull	2.1	60,722	1.7	Loam
	2	Thick duff mull	2.4	64,112	1.8	Sandy loam
	3	Thick duff mull	4.3	105,786	1.5	Sandy loam
	4	Thick duff mull	3.6	94,384	1.4	Sandy loam
	5	Felty mor	2.3	53,861	1.8	Gravelly loamy sand
	6	Thick duff mull	5.1	124,593	1.3	Sandy loam
	7	Thick duff mull	4.1	109,069	1.1	Loamy sand
	8	Thick duff mull	3.7	130,472	1.9	Gravelly silt loam
	9	Thick duff mull	2.6	51,318	1.1	Loamy sand
	10	Thick duff mull	2.2	57,198	1.8	Loam
	11	Thick duff mull	2.2	74,854	1.7	Sandy loam
	12	Thin duff mull	2.0	52,951	1.6	Sandy loam
	13	Thin duff mull	1.9	51,684	1.3	Sandy loam
	14	Thin duff mull	1.5	57,626	1.3	Loam
Province means			2.9	77,759	1.5	
All plot means			1.8	56,754	2.2	

The forest floor is thinnest where the humus type is fine mull (table 3). Felty mor and thin duff mull types appear intermediate and roughly equivalent in depth and weight. Thick duff mull is characterized by the greatest accumulations of organic materials, as evidenced by both depth and weight figures.

Table 3.--Weight and depth characteristics of the humus types

Humus type	Number of plots	Thickness		Weight	
		Average	Range	Average	Range
		Inches		Pounds per acre	
Felty mor	18	1.7	1.1 to 3.2	61,423	32,814 to 152,375
Fine mull	14	.8	.5 to 1.1	30,013	16,987 to 44,038
Thin duff mull	4	1.7	1.5 to 2.0	53,092	50,105 to 57,626
Thick duff mull	10	3.2	2.1 to 5.1	87,251	51,318 to 130,472

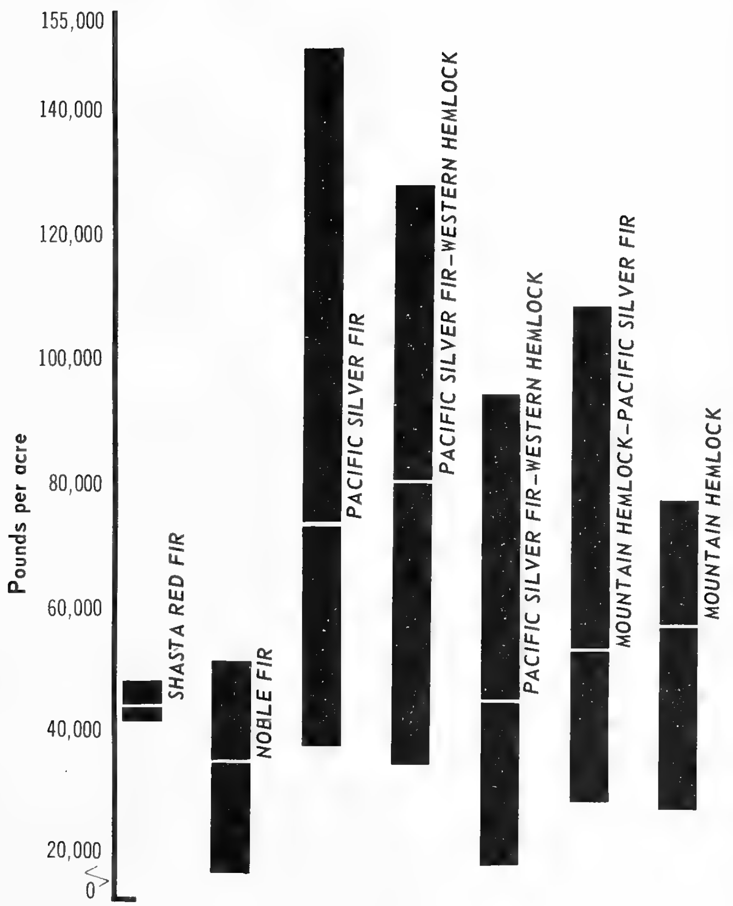
Average weight of thick duff mulls agrees quite closely with an average weight of 89,219 pounds per acre, previously reported for duff mulls in Washington by Gessel and Balci (1965). However, they report a substantially higher weight for mor humus types (140,862 pounds per acre) than was found in this study. This discrepancy may be partially due to the classification of some forest floor layers in this study as A1 horizons, which might be classed as H layers according to other systems.

Apparently, forest floor weights tend to be somewhat higher under mature true fir—hemlock stands than under 100-year-old Douglas-fir stands in Oregon. Youngberg (1966) reports a range of 20,475 to 59,677 pounds per acre for Douglas-fir in the Oregon Coast Ranges, with most values being in the 20,000 to 30,000 pounds per acre range. Tarrant and Miller (1963) also found this same range at Wind River in southwestern Washington.

Stands dominated by noble fir had the smallest quantities of forest floor material (fig. 2). Pacific silver fir and Pacific silver fir–western hemlock plots, on the other hand, had substantially greater accumulations of material than the other types.

Attempts were made to determine whether correlations existed between forest floor characteristics and plot elevation, aspect, and understory vegetation. In each case, there was no apparent relationship. With a larger sample size such correlations would perhaps become detectable.

Figure 2.--Forest floor weight under seven forest types. ***(The horizontal line is the average for the type, and the length of the bar represents the range.)***



Forest Floor Characteristics--Nutrient Content

Chemical analyses of forest floor material disclosed considerable variability in nutrient content among plots (table 4). For example, available phosphorus content ranged from 21 to 180 parts per million (p. p. m.) and total nitrogen content varied from 0. 698 to 1. 395 percent. This variability, coupled with the small sample available, makes it difficult to develop relationships. Suggested correlations between forest floor nutrient content and ecological province or forest type are, therefore, tentative.

Table 4.--Content of available nutrients in forest floor material collected from 46 true fir--hemlock stands in the Cascade Range of Oregon and Washington

Province and number of plots	Phosphorus		Nitrogen		Potassium		Calcium		Magnesium	
	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
	P.p.m.		Percent		Meq. per 100 g.		Meq. per 100 g.		Meq. per 100 g.	
Crater Lake, Oreg.; 6 plots	55	32 to 68	0.862	0.753 to .993	2.35	1.30 to 3.12	10.3	5.0 to 3.12	4.5	2.2 to 8.0
Three Sisters, Oreg.; 2 plots	50	36 to 63	.878	.698 to 1.067	2.28	1.56 to 3.00	14.2	6.4 to 22.0	5.2	3.8 to 6.7
Willamette, Oreg.; 3 plots	51	45 to 59	1.135	.970 to 1.326	2.06	1.96 to 2.22	14.9	11.6 to 17.8	5.4	4.5 to 6.0
Mount Hood, Oreg.; 6 plots	62	53 to 75	.955	.785 to 1.090	2.59	1.44 to 3.40	14.6	9.0 to 22.5	5.5	3.2 to 6.7
Mount Adams, Wash.; 6 plots	78	45 to 124	1.086	1.016 to 1.203	2.45	1.76 to 3.68	14.6	6.4 to 26.7	5.3	3.8 to 6.7
Mount Rainier, Wash.; 9 plots	103	41 to 180	1.054	.871 to 1.266	2.62	1.44 to 3.48	13.3	5.2 to 25.5	5.1	3.5 to 7.0
Mount Baker, Wash.; 14 plots	69	21 to 130	1.026	.815 to 1.395	2.56	1.47 to 4.18	12.1	5.4 to 32.1	4.6	3.3 to 6.2
All provinces; 46 plots	72	21 to 180	1.009	.698 to 1.395	2.46	1.30 to 4.18	13.01	5.0 to 32.1	5.0	2.2 to 8.0

Mean values for forest floor nutrient levels generally show little relationship to ecological province (table 4). This is especially true for exchangeable potassium, calcium, and magnesium values, which vary only slightly among provinces. Values for total N suggest levels of this important nutrient element

may be slightly lower in the Crater Lake and Three Sisters Provinces. Available phosphorus content of forest floor material tends to be greater in the three Washington provinces.

There are several interesting correlations between forest floor nutrient content and forest type (figs. 3, 4, and 5). Forest floors in Shasta red fir and mountain hemlock stands tend to have smallest amounts of total nitrogen, available phosphorus, and exchangeable calcium; quantities appear even smaller when the relatively small accumulations of forest floor material in these two types are considered. Forest floors under Pacific silver fir stands contained appreciably greater quantities of available phosphorus (fig. 4). Levels of exchangeable calcium were substantially higher under noble fir stands than under the other six forest types (fig. 5). Why these differences occur is not known, but they do reflect the possibility of differing nutrient requirements on the part of the various tree species or, perhaps more likely, differences in soil parent materials.

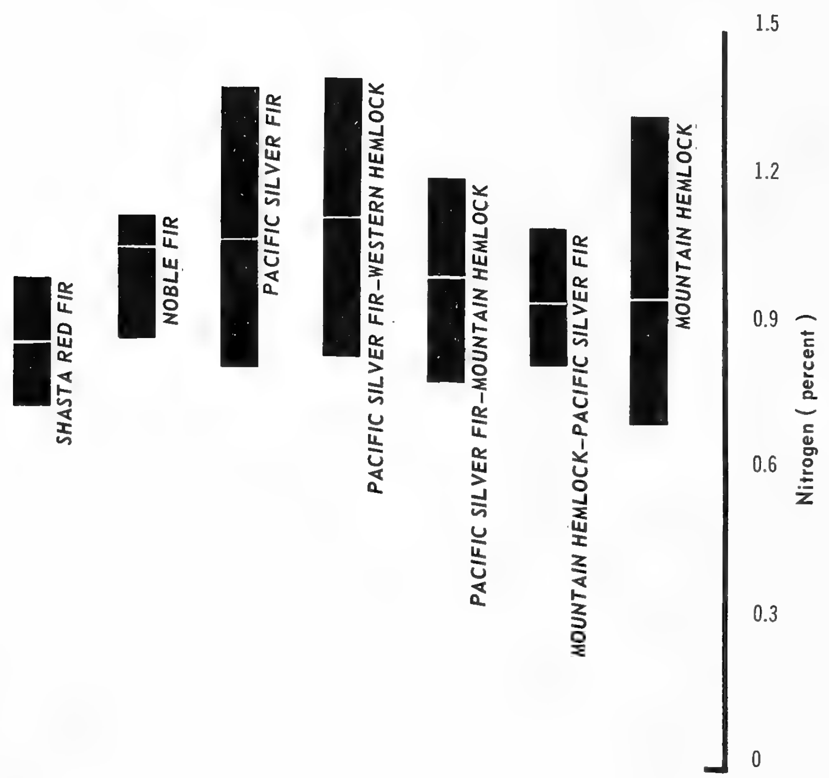


Figure 3.--Amount of total nitrogen in forest floors under seven forest types. *(The horizontal line is the average for the type, and the length of the bar represents the range.)*

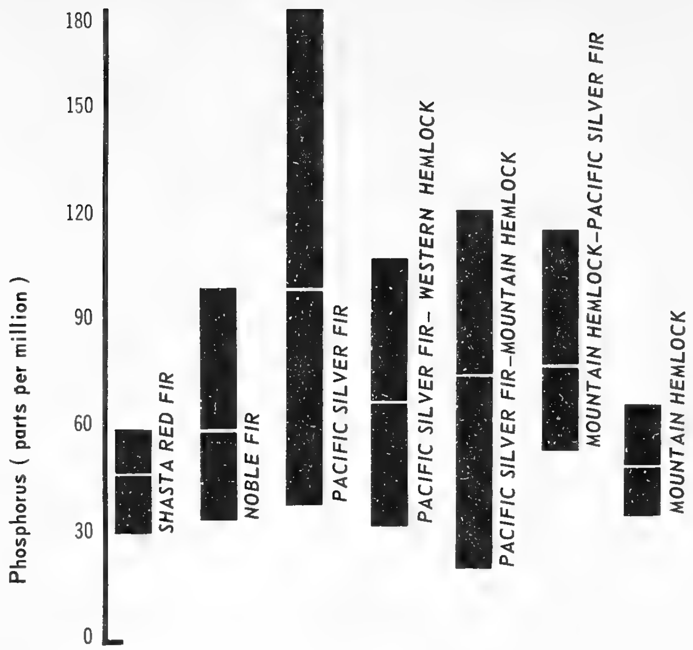


Figure 4.--Amount of available phosphorus in forest floors under seven forest types. *(The horizontal line is the average for the type, and the length of the bar represents the range.)*

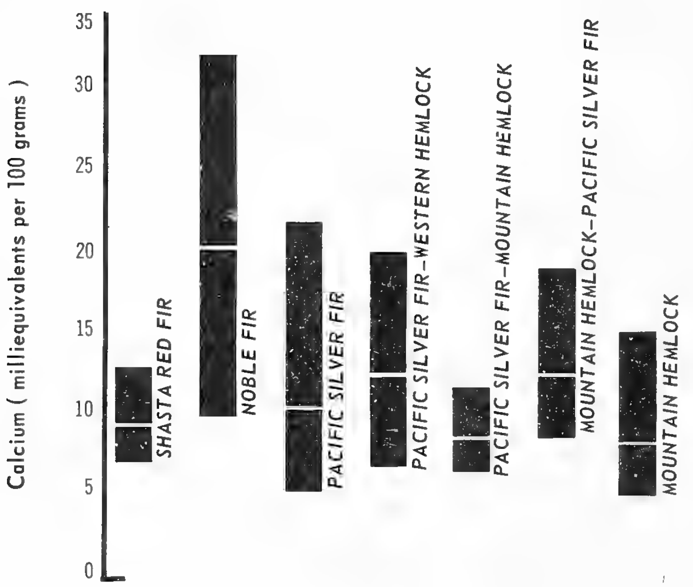


Figure 5.--Amount of exchangeable calcium in forest floors under seven forest types. *(The horizontal line is the average for the type, and the length of the bar represents the range.)*

Forest Floor-Soil Fertility Relationships

An important objective of this study was to determine the proportion of the total available nutrient capital contained in the forest floor. Thus, nutrient concentration levels were converted to weight in pounds per acre for both the mineral soil and forest floor (table 5). It should be borne in mind that the soil nutrient contents are only approximations since the method of determining depth (restriction of penetration with a King tube) is not an entirely accurate measure of rooting depth.

Nutrient levels in mineral soil vary strikingly from plot to plot. Much of this variability is explainable by differences in soil profile depths. However, if the mean values for the 46 plots are considered, it appears that fertility levels of these soils are generally well within the range of values reported for Cascade Range soils. The surface 6 inches of soil in the Cascades is reported to have a nitrogen content of about 3,800 to 6,600 pounds per acre and an available phosphorus content of from 7 to 100 pounds per acre (Forest Soils Committee of the Douglas-fir Region 1957). Average quantities of these elements determined in this study (7,895 pounds per acre of nitrogen and 28 pounds per acre of phosphorus) appear at least roughly comparable, since the major portion of these elements is generally in the surface soil.

Nutrient quantities contained in the forest floor also show considerable variation among plots (table 5). Most can be attributed to variations in weight of forest floor material but part is due to some variations in concentration.

Ranges in percentages of total nutrient quantities (in soil plus forest floor) contained in the forest floor are: available phosphorus, 1.8 to 85.1 percent; exchangeable potassium, 1.4 to 70.8 percent; exchangeable calcium, 1.0 to 8.05 percent; exchangeable magnesium, 3.6 to 79.9 percent; and total nitrogen, 0.2 to 39.4 percent. In the majority of cases where substantial proportions of the total available nutrient capital are contained in the forest floor, the soil profile was shallow.

It should be emphasized that, with the exception of nitrogen, amounts of available nutrients, rather than total quantities, have been determined in this study. If total quantities had been measured, the forest floor might have been found to contain a higher proportion of at least some of the nutrient elements, such as phosphorus.

Mean percentages for all plots (table 5) indicate that generally less than one-fourth of the total available nutrient supply is contained in the forest floor material. This proportion is even smaller in the case of total nitrogen (12 percent). The proportion of nutrients contained in the forest floor is greatest for the Mount Baker Province, largely due to the thicker accumulations of forest floor material.

From these analytical results it is tentatively concluded that levels of most nutrients are adequate for satisfactory tree growth. Phosphorus may be the most limiting element on some shallow soils. Despite the large quantities of total nitrogen present, no definite conclusions can be drawn concerning the nitrogen economy until rates at which it is converted into available forms are determined.

Table 5.--Amounts of exchangeable potassium, calcium, magnesium, available phosphorus and total nitrogen in the

Ecological province	Plot No.	Mineral soil					
		Available phosphorus	Exchangeable potassium	Exchangeable calcium	Exchangeable magnesium	Total nitrogen	pH
		Pounds per acre					
Crater Lake, Oregon	1	39	222	894	149	2,437	5.7
	2	54	968	5,939	503	8,496	5.5
	3	15	147	322	6	2,202	5.2
	4	22	408	895	182	18,279	4.6
	5	27	351	988	110	5,792	5.1
	6	26	621	353	215	5,475	5.4
Province means		30	453	1,560	144	7,114	5.6
Three Sisters, Oregon	1	19	1,103	1,916	325	6,335	5.4
	2	16	980	638	167	3,374	5.8
Province means		18	1,042	1,277	246	4,854	5.6
Willamette, Oregon	1	30	944	644	196	11,859	5.3
	2	109	325	208	254	18,296	4.5
	3	12	66	85	26	679	6.2
Province means		50	445	312	159	10,278	5.3
Mount Hood, Oregon	1	17	264	150	92	7,504	4.4
	2	44	379	194	118	14,136	4.9
	3	20	308	215	87	1,574	5.9
	4	22	354	130	79	8,448	5.1
	5	29	51	348	53	1,718	5.8
	6	3	163	89	54	4,090	5.0
Province means		22	253	188	80	6,245	5.2
Mount Adams, Washington	1	33	630	1,025	179	7,904	5.9
	2	32	1,511	644	262	7,621	5.6
	3	21	837	571	261	40,754	5.4
	4	27	178	304	93	4,027	5.9
	5	48	617	351	107	5,964	5.6
	6	35	201	258	78	4,636	5,7
Province means		33	662	526	163	11,818	5.7
Mount Rainier, Washington	1	2	51	66	20	2,480	5.4
	2	10	202	841	197	3,720	5.6
	3	22	587	5,008	382	11,268	6.0
	4	111	46	467	143	9,137	5.4
	5	57	1,890	4,960	776	20,983	5.9
	6	32	502	321	98	5,772	5.3
	7	33	1,163	396	161	4,035	6.0
	8	16	428	313	95	10,872	5.1
	9	25	1,061	3,949	452	39,856	5.0
Province means		34	659	1,813	258	12,014	5.5
Mount Baker, Washington	1	15	296	152	46	8,144	5.8
	2	18	158	242	49	2,867	6.1
	3	22	198	218	88	2,357	5.3
	4	20	260	295	45	2,031	6.0
	5	10	252	763	107	7,102	5.1
	6	14	136	39	47	3,728	4.9
	7	8	108	46	28	4,806	4.9
	8	8	272	321	130	3,250	5.6
	9	15	256	328	200	3,913	4.5
	10	31	194	165	50	2,812	5.7
	11	9	301	3,150	470	14,912	4.3
	12	52	230	590	103	1,558	5.3
	13	29	568	1,004	258	2,959	5.6
	14	32	253	176	36	3,026	5.5
Province means		20	249	535	118	4,533	5.3
Averages for all plots		28	467	891	165	7,895	5.4

mineral soil and forest floor material and proportion contained in the forest floor alone, by ecological provinces and plots

Forest floor material						Forest floor material alone				
Available phosphorus	Exchangeable potassium	Exchangeable calcium	Exchangeable magnesium	Total nitrogen	pH	Available phosphorus	Exchangeable potassium	Exchangeable calcium	Exchangeable magnesium	Total nitrogen
Pounds per acre						Percent				
2	36	84	31	367	5.0	4	14	9	17	13
3	50	62	20	368	4.4	5	5	1	4	4
4	66	76	26	688	4.3	20	31	19	80	24
2	42	172	25	319	4.9	10	9	16	12	2
2	53	116	43	434	5.2	8	13	10	28	7
3	24	56	13	413	4.0	11	4	14	6	7
3	45	94	26	432	4.6	10	13	12	24	10
3	48	100	36	546	4.6	13	4	5	10	8
1	27	101	19	246	4.6	8	3	14	10	7
2	38	100	28	396	4.6	10	4	10	10	8
3	34	102	24	427	4.8	9	3	14	11	4
2	38	157	32	490	4.9	2	10	43	11	3
1	23	89	20	388	4.6	8	26	51	44	36
2	32	116	25	435	4.8	6	13	36	22	14
2	20	95	21	247	4.4	9	7	39	19	3
1	11	23	8	157	4.4	3	3	11	6	1
3	44	160	28	374	4.8	12	12	43	25	19
2	51	69	26	348	4.4	8	1	35	25	4
2	42	126	27	358	4.6	7	45	27	34	17
1	26	52	16	284	4.3	25	14	37	22	6
2	32	88	21	295	4.5	11	14	32	22	8
9	65	157	64	1,135	3.8	22	9	13	26	12
4	44	132	25	559	4.3	11	3	17	9	7
6	67	60	30	497	4.0	21	7	10	10	1
3	46	78	21	394	4.1	10	20	20	19	9
1	13	80	12	185	4.6	2	2	19	10	3
1	25	156	24	321	5.0	4	11	38	23	6
4	43	110	29	515	4.3	12	9	20	16	6
14	124	189	72	1,615	3.9	85	71	74	78	39
2	26	93	23	444	4.3	16	11	10	10	11
22	166	280	84	1,115	4.0	50	22	5	18	9
5	62	145	32	436	4.2	4	58	23	18	5
4	33	126	29	435	4.8	6	2	2	4	2
4	43	119	20	350	4.6	10	8	27	17	6
3	29	50	15	386	3.9	9	2	11	8	9
6	48	79	28	511	3.9	27	10	20	23	5
2	26	129	19	252	4.7	6	2	3	4	1
7	62	134	36	616	4.2	24	21	19	20	10
4	66	124	44	659	4.0	19	18	45	49	8
8	49	69	28	882	3.8	31	24	22	36	24
6	75	148	43	955	3.6	22	28	40	32	29
2	80	164	41	769	3.8	9	23	36	48	28
2	62	118	32	553	3.8	19	20	13	23	7
4	-106	444	58	1,574	3.9	23	44	92	55	30
11	142	190	54	1,076	3.8	57	57	80	66	18
10	75	177	72	1,079	3.8	11	22	36	35	25
6	63	92	38	716	3.9	26	20	29	16	16
1	63	120	29	710	4.0	2	24	42	36	20
3	51	305	36	850	4.1	27	14	9	7	5
2	50	346	39	594	4.8	3	18	37	28	28
4	84	125	39	520	4.4	12	13	11	13	15
4	68	105	29	691	3.9	12	21	37	45	19
5	74	180	42	830	4.0	20	25	38	35	19
4	54	131	32	581	4.3	16	17	26	25	12

SUMMARY and CONCLUSIONS

This exploratory study has indicated that forest floors under true fir-hemlock stands in Oregon and Washington generally attain only moderate thickness. Average forest floor depth on 46 plots was 1.8 inches and average weight was 56,754 pounds per acre. Forest floor thickness and weight were generally greatest in the northern ecological provinces (Mount Rainier and Mount Baker). A felty mor humus type predominated in the southern provinces (Crater Lake, Three Sisters, and Willamette). Plots in the Mount Baker Province had largely duff-mull humus types. Plots within the Mount Hood, Mount Adams, and Mount Rainier Provinces had predominately fine mull or felty mor humus types.

Nutrient content of forest floor material varied greatly from plot to plot, and there was little apparent correlation between nutrient content and ecological province. Available phosphorus content appeared considerably higher under Pacific silver fir stands, and noble fir forest floors contained distinctly more exchangeable calcium. Except for these rather striking relationships, forest floor nutrient content was virtually uniform among forest types.

Results of analyses of both forest soil and underlying mineral soil indicate that less than one-fourth of the total available nutrient supply is generally contained in the forest floor material. Furthermore, with the possible exception of phosphorus, levels of available nutrients appear to be adequate for good tree growth.

This study has provided preliminary information concerning general characteristics of upper-slope forest floors in the Cascade Range of Oregon and Washington. However, there is much work yet to do. Large local variations in forest floor characteristics necessitate much more extensive sampling to fully describe these layers. Questions remaining unanswered include moisture relationships of the forest floor, the effect of organic layers on tree regeneration, total amounts of nutrient elements contained in the forest floor, and factors affecting rates of mineralization.

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